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The origin of the diorites and associated rocks of Chouet, north-western Guernsey, Channel Islands

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SYNOPSIS

A NUMBER of diorite complexes occur within the Channel Islands region, notably on Jersey, Alderney, and particularly Guernsey. Much of northern Guernsey is made up of the largest of these complexes (fig. S1), the Bordeaux diorite. In the north-western part of this diorite, around Chouet, a complicated association of plutonic rocks occurs. Although the field relationships in this area are sometimes difficult to interpret—this is often the case in diorite complexes—three separate groups of rocks may be distinguished within the association: a diorite group; a granodiorite group; and an inhomogeneous suite of rocks (fig. S2).

The widespread *diorite group* consists predominantly of an even-grained diorite, which is relatively homogeneous but which occasionally grades into an acicular diorite, the latter often containing pods and veins of appinite. The *granodiorite group* is the least common, occurring as bodies which are interpreted as intrusive sheets and bosses within the even-grained diorite, but occurring as angular blocks within the inhomogeneous suite of rocks. The granodiorite invariably contains rounded diorite xenoliths. The *inhomogeneous suite* consists of a variety of rocks from patchy, dark diorite, through quartz diorite to tonalite. Commonly, these rock types are intimately associated, often showing gradational contacts with each other and frequently with the more basic portions occurring as 'xenolithic' material within the more acidic portions. At contacts between the inhomogeneous suite and the even-grained diorite certain features (e.g. lobate margins and pipe-like structures) indicate that the diorite must have been close to its solidus temperature at the time of emplacement of the inhomogeneous suite. The field relationships between the three groups are interpreted as indicating that the diorite group was emplaced first, followed by the granodiorite group, with both

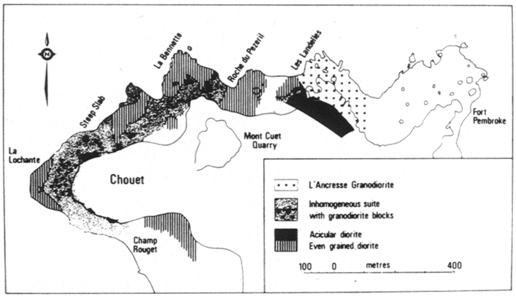

FIG. S2. Geological map of the Chouet area, Guernsey.

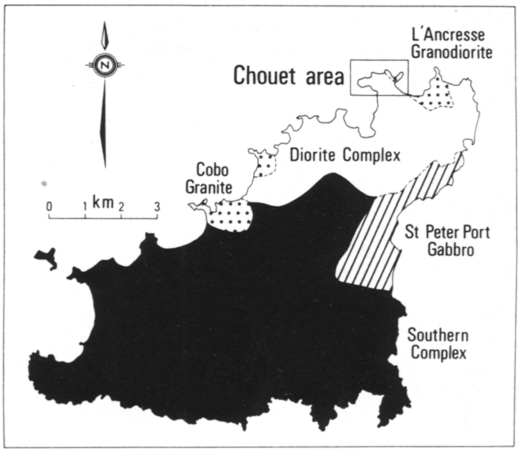

FIG. S1. Simplified geological map of Guernsey, Channel Islands.

of these clearly pre-dating the inhomogeneous suite.

Fifty-nine specimens, chosen to give a representative sample of each of the three rock groups, have been analysed for major, minor, and a selection of trace elements and thirteen of these specimens have been analysed for *REE*. The chemistry of the analysed rocks confirms the division into three groups, with each group showing distinctive characteristics. Furthermore, chemical plots (e.g. Al_2O_3, P_2O_5, Cr, and Ni *v.* SiO_2) show discontinuities and areas of overlap between each group which cannot be explained within the constraints of a single genetic model relating the three groups to each other. This argument is particularly strong for the relationship between the diorite group, which spans the range 50 to 59% SiO_2, and the inhomogeneous suite, spanning the range 53 to 68% SiO_2. In the area of overlap (53 to 59% SiO_2) the two groups are geochemically different. Therefore, for a variety of reasons, including emplacement order, the geochemical characteristics of the groups and the lithological inhomogeneity which is associated only with the chemically intermediate members of the association (the inhomogeneous suite), three quite different and genetically unrelated liquids are required to generate the three groups of rocks.

The even-grained diorite shows chemical variation (e.g. with increasing SiO_2, decreasing Al_2O_3, MgO, CaO, Sc, V, Cr, and Ni, and increasing Na_2O, La, Nd, and Y) consistent with amphibole + plagioclase fractionation up to 55% SiO_2. At 55% SiO_2 several elements show a change of slope (e.g. $FeO + Fe_2O_3$, TiO_2, Rb, Ba, and Zr) indicating the introduction of biotite as a fractionating phase. Increasing total *REE* content with increasing SiO_2 throughout the even-grained diorite supports the contention that amphibole is an important fractionating phase. The higher TiO_2, P_2O_5, Sr, La, Ce, Nd, and Y contents and negligible Cr and Ni contents of the acicular diorite suggest an origin by delayed crystallization of volatile-enriched portions of the diorite group magma.

The granodiorite group shows little geochemical variation. Members of this group contain detectable amounts of Cr and Ni, unlike virtually all members of the inhomogeneous suite. For this reason, and because of the field relationships, the granodiorite is considered to be genetically unrelated to members of the inhomogeneous suite and a separate liquid is thus required for its genesis. This liquid may have been the fractionated derivative of some other magma (though if this is so the 'parent' is entirely unrepresented at the present erosion level) or it may represent a direct crustal melt. Diorite xenoliths within the granodiorite are chemically similar to the even-grained diorite.

Despite the lithological complexity of the inhomogeneous suite, its geochemical unity is clearly established in that, for instance, virtually none of the members of the suite (including even the most SiO_2-poor) contain detectable Cr and Ni. Moreover, geochemical variation within the group is rational (with the possible exceptions of Sr, Zr, and Ba) and may be explained in terms of a crystal fractionation model. However, the fractionation must have acted on a liquid itself unrelated to either the diorite or granodiorite group magmas. An additional complication is that later derivative liquids intrude into and partly digest earlier-formed semi-solids of the suite to produce much of the observed inhomogeneity. The phases which have controlled fractionation within the suite include plagioclase (established petrographically as well as geochemically) and hornblende. The role of apatite is uncertain. The fractionation of hornblende is particularly useful in explaining the change in *REE* contents within the inhomogeneous suite. Total *REE* contents increase from the dark diorite to the quartz diorite, but decrease from the quartz diorite to the tonalite with concomitant relative *HREE* depletion. This is taken to be a reflection of the changing hornblende/liquid partition coefficients for *REE* with increasing SiO_2, which are less than one for liquids of basaltic and andesitic composition but greater than one for liquids of dacitic composition.

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THE ORIGIN OF THE DIORITES AND ASSOCIATED ROCKS OF CHOUET, NORTH-WESTERN GUERNSEY, CHANNEL ISLANDS

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DIORITES feature prominently in the geology of the Channel Islands. Diorite complexes occur on Jersey (Wells and Bishop, 1955; Key, 1977), on Alderney (Nockolds, 1932)and on Guernsey (Drysdall, 1957; Roach, 1964, 1966). This paper gives the results of a detailed study of the diorites and associated rocks from a restricted area around Chouet in north-western Guernsey. It utilises the field relations, petrography and geochemistry of the rocks to place limits on models which may be proposed for their origin.

In the Chouet area the diorite complex may be subdivided into a diorite group, a granodiorite group and a suite of inhomogeneous rocks (Table I). The diorite group consists of an even-grained diorite and an acicular diorite and is equivalent to part of the Bordeaux diorite (Roach, 1966) which has been assigned a late Precambrian age (Bishop et al., 1975). The inhomogeneous suite, which post-dates the diorite group, ranges in composition often on an outcrop scale from dark diorite through quartz diorite to tonalite. The third group of rocks consists predominantly of a distinctive coarse-grained granodiorite.

Table I. Summary of Rock Groups established in Chouet.

Rock Group	Lithologies	Occurrence
Inhomogeneous Suite	Patchy and variable from "xenolithic" dark diorite through quartz diorite to tonalite.	Variably shaped intrusions into diorite group, frequently most leucocratic at margins.
Granodiorite Group	Course-grained leucocratic granodiorite and trondhjemite with rounded dioritic xenoliths.	Sheets and bosses in the diorite group. Angular blocks and xenoliths in the inhomogeneous suite.
Diorite Group	Homogeneous even-grained diorite transitional to acicular diorite with pods and veins of appinite.	Earliest rock group into which the other two groups of rocks intrude.

Field relationships

Field relationships in dioritic rocks are notoriously difficult to interpret and it must be emphasised that the relationships occurring within the small area of Chouet are extremely complex. It is only possible here to give those details which have enabled the unity of the groups to be distinguished, the variability within groups to be recognised and the relationships between the groups to be established. Localities referred to in the text are shown in fig. 2 of the synopsis.

The diorite group. A melanocratic to mesocratic even-grained diorite, containing equant amphibole and plagioclase, occurs at a number of localities within the area studied. This, the dominant member of the diorite group, is comparatively homogeneous on outcrop scale, except at certain localities (e.g. Les Landelles) where it grades into a diorite with markedly acicular, prismatic amphibole. A transitional zone of diorite with a mixture of equant and acicular amphibole crystals is always present and this gradation has led us to treat these rock types as belonging to a single group. At Les Landelles the acicular diorite contains pods and veins of appinite (the term appinite is used in the sense of Wells and Bishop (1955) to describe pegmatitic diorite characterised by prismatic amphibole). The prismatic amphibole crystals within the appinite vary from 20 to 40 mm in length and are commonly cored with plagioclase feldspar in the manner figured by Wells and Bishop (1955).

The granodiorite group. The granodiorite can be readily recognised in the field as a yellow weathering, coarse-grained granitic rock with obvious quartz aggregates. In addition, it characteristically contains rounded, distinct xenoliths from a few tens to a few hundreds of millimetres across of variably feldspathised even-grained diorite.

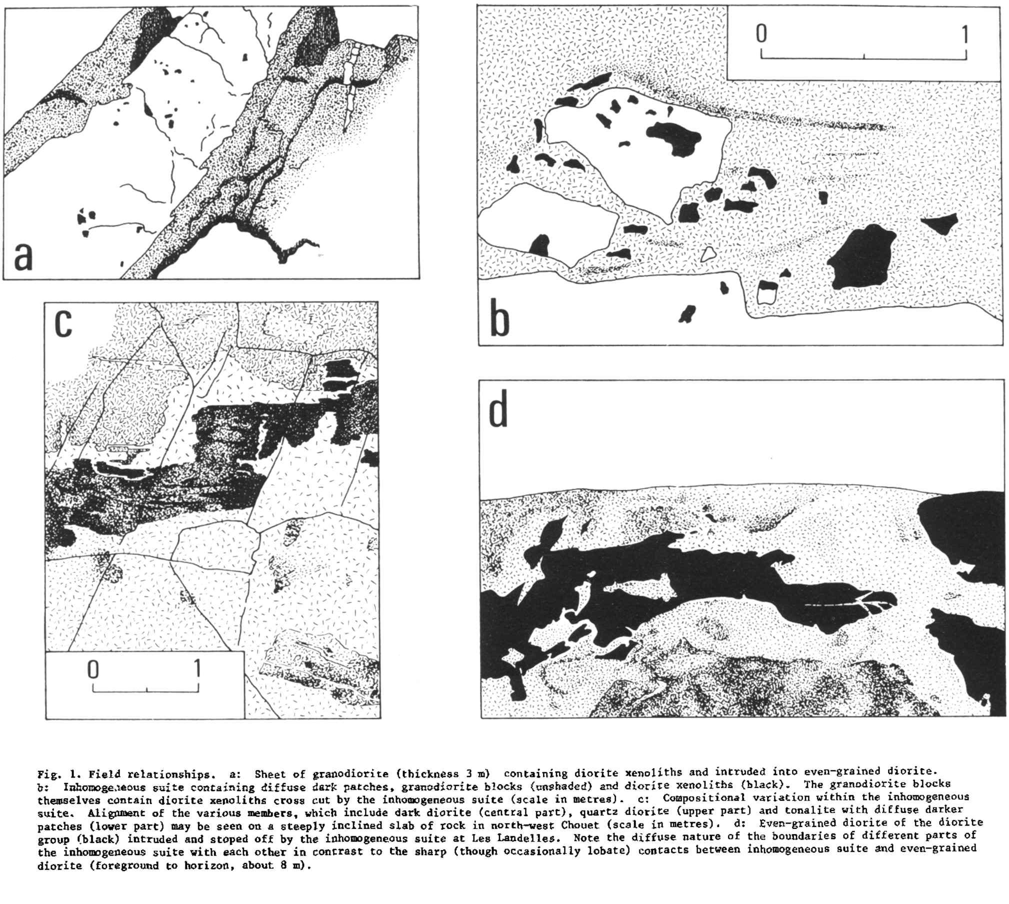

Fig. 1. Field relationships. a: Sheet of granodiorite (thickness 3 m) containing diorite xenoliths and intruded into even-grained diorite. b: Inhomogeneous suite containing diffuse dark patches, granodiorite blocks (unshaded) and diorite xenoliths (black). The granodiorite blocks themselves contain diorite xenoliths cross cut by the inhomogeneous suite (scale in metres). c: Compositional variation within the inhomogeneous suite. Alignment of the various members, which include dark diorite (central part), quartz diorite (upper part) and tonalite with diffuse darker patches (lower part) may be seen on a steeply inclined slab of rock in north-west Chouet (scale in metres). d: Even-grained diorite of the diorite group (black) intruded and stoped off by the inhomogeneous suite at Les Landelles. Note the diffuse nature of the boundaries of different parts of the inhomogeneous suite with each other in contrast to the sharp (though occasionally lobate) contacts between inhomogeneous suite and even-grained diorite (foreground to horizon, about 8 m).

Table II. Major element analyses (weight percent), selected trace element analyses (p.p.m.) and CIPW norms of rocks from Chouet, north-western Guernsey, Channel Islands.

	GC 1	GC 2	GC 22	GC 32	GC 33	GC 34	GC 35	GC 36	GC 38	GC 3	GC 4	GC 5	GC 6	GC 39	GC 40	GC 41
SiO_2	58.39	57.06	53.85	53.81	51.43	50.57	54.71	57.72	51.66	53.96	53.28	55.09	52.77	51.30	51.73	50.33
TiO_2	0.75	0.85	1.37	0.64	0.87	0.68	1.11	0.89	0.97	1.08	1.13	1.26	1.40	1.58	1.31	1.62
Al_2O_3	17.92	17.58	18.23	18.90	18.41	19.83	18.61	16.65	18.03	19.91	20.18	17.82	18.20	18.31	20.06	17.96
Fe_2O_3	1.12	1.69	2.19	1.99	2.36	2.36	2.21	2.00	2.58	1.71	2.30	2.45	2.72	3.16	2.01	3.98
FeO	5.51	5.65	7.16	6.63	6.33	5.57	6.04	5.45	6.81	6.12	5.72	5.99	6.63	7.14	7.01	6.82
MnO	0.31	0.14	0.14	0.19	0.17	0.17	0.14	0.18	0.22	0.15	0.16	0.19	0.19	0.20	0.16	0.16
MgO	3.79	4.29	3.72	5.03	6.35	6.79	4.63	4.33	5.95	3.84	3.87	3.86	4.48	4.89	4.13	5.21
CaO	7.20	8.09	7.59	7.68	10.11	10.30	7.45	8.15	8.85	8.09	8.12	7.59	8.66	8.57	8.00	8.82
Na_2O	3.31	3.00	3.50	3.09	2.53	2.42	2.80	2.91	2.87	3.44	3.47	3.45	3.22	3.12	3.54	3.39
K_2O	1.67	1.47	1.94	1.95	1.32	1.19	2.19	1.56	1.87	1.45	1.51	2.02	1.47	1.55	1.77	1.54
P_2O_5	0.19	0.18	0.31	0.09	0.11	0.10	0.11	0.17	0.19	0.26	0.26	0.28	0.24	0.18	0.27	0.17
Sc	22	30	29	24	39	38	30	29	35	27	27	33	34	38	29	40
V	138	163	280	147	233	180	209	184	210	185	187	216	305	367	224	384
Cr	31	37	n.f.	24	70	62	17	56	113	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.
Ni	15	15	n.f.	15	27	24	14	23	44	3	3	n.f.	n.f.	n.f.	n.f.	n.f.
Zn	63	64	84	80	75	69	73	68	84	71	71	72	79	99	72	90
Rb	49	42	57	74	42	33	79	55	69	42	46	72	49	53	62	52
Sr	442	429	543	484	396	426	431	366	449	507	514	470	514	474	565	478
Y	20	32	21	18	13	11	17	22	20	20	21	26	21	21	24	17
Zr	111	175	137	100	66	58	181	98	97	153	164	117	119	102	152	85
Ba	556	457	563	408	242	238	619	450	470	510	495	606	362	366	477	327
La	21	26	24	32	10	10	20	18	21	23	29	25	25	17	21	20
Ce	46	50	46	57	22	23	39	39	53	47	56	51	47	44	46	38
Nd	33	39	30	31	13	14	25	26	35	30	30	33	28	25	29	22
Q	9.63	9.11	2.49	1.38	0.07	-	4.94	10.61	-	3.11	2.44	4.61	2.48	0.44	-	-
C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
or	9.87	8.57	11.44	11.55	7.80	7.02	12.97	9.22	11.08	8.57	8.92	11.96	8.69	9.17	10.48	9.11
ab	28.00	29.14	29.60	26.17	21.39	20.52	23.68	24.60	24.30	29.14	29.38	29.22	27.28	26.44	29.93	28.65
an	29.10	34.58	28.32	31.91	34.99	39.72	31.72	27.78	30.76	34.58	35.01	27.14	30.85	31.34	33.61	29.25
di	4.44	3.15	6.05	4.58	11.73	8.66	3.69	9.42	9.68	3.15	2.92	7.11	8.63	8.16	3.56	10.85
hy	15.45	16.33	15.60	20.09	18.70	16.31	17.43	13.41	15.15	16.33	15.25	13.37	14.90	16.44	12.23	8.45
ol	-	-	-	-	-	2.81	-	-	3.01	-	-	-	-	-	4.16	4.44
mt	1.63	2.48	3.18	2.88	3.43	3.43	3.21	2.89	3.75	2.48	3.32	3.55	3.95	4.59	2.91	5.77
il	1.43	2.05	2.60	1.23	1.65	1.30	2.10	1.68	1.84	2.05	2.14	2.39	2.66	3.01	2.49	3.08
ap	0.44	0.61	0.72	0.21	0.26	0.23	0.26	0.40	0.44	0.61	0.61	0.65	0.56	0.42	0.63	0.40

	GC 15	GC 16	GC 47	GC 92	GC 9	GC 10	GC 14	GC 21	GC 37	GC 46	GC 25	GC 26	GC 48	GC 72
SiO_2	54.79	58.71	52.43	55.55	67.16	67.54	66.66	67.59	68.22	69.08	53.26	58.24	54.58	53.63
TiO_2	1.16	0.80	1.33	0.89	0.50	0.51	0.62	0.53	0.89	0.46	1.27	0.96	1.24	1.28
Al_2O_3	19.37	17.24	18.04	17.63	15.94	15.82	15.92	15.63	16.65	15.10	18.73	18.42	17.50	18.53
Fe_2O_3	2.41	2.15	3.11	2.90	1.81	1.29	1.25	1.43	2.00	1.57	2.41	1.95	2.29	1.83
FeO	5.75	5.03	7.43	5.96	2.38	2.76	3.13	2.92	5.45	2.23	6.19	5.51	7.26	7.59
MnO	0.14	0.17	0.20	0.21	0.07	0.07	0.06	0.08	0.18	0.08	0.19	0.16	0.17	0.21
MgO	4.05	3.63	4.45	3.96	1.61	1.61	1.86	1.69	4.33	1.38	3.78	3.03	4.30	4.31
CaO	5.58	6.07	8.21	6.65	3.92	3.81	4.47	4.17	8.15	2.79	7.44	5.45	7.71	7.32
Na_2O	3.74	4.17	2.95	4.70	4.07	4.00	3.61	3.90	2.91	3.39	4.49	3.78	2.90	3.34
K_2O	2.75	1.83	1.66	1.39	2.41	2.46	2.25	1.93	1.56	3.83	1.64	2.16	1.83	1.79
P_2O_5	0.27	0.19	0.19	0.17	0.12	0.13	0.17	0.13	0.17	0.10	0.59	0.33	0.20	0.17
Sc	21	26	37	36	10	11	10	11	8	9	37	30	32	35
V	132	106	343	134	54	53	52	53	54	48	126	109	274	267
Cr	11	41	n.f.	50	12	11	9	10	14	10	n.f.	n.f.	n.f.	n.f.
Ni	6	11	n.f.	6	4	4	3	3	4	4	n.f.	n.f.	n.f.	n.f.
Zn	76	63	87	81	39	31	30	38	31	31	91	74	79	123
Rb	113	78	56	51	65	67	70	57	61	103	57	75	66	65
Sr	496	397	409	397	401	399	476	427	459	363	504	520	447	662
Y	22	39	19	50	14	12	9	11	5	12	42	27	20	15
Zr	145	110	93	174	139	133	150	147	116	123	71	23	90	165
Ba	874	519	542	397	632	668	617	701	551	749	386	567	486	425
La	18	17	26	17	26	21	25	36	24	25	29	27	23	17
Ce	33	37	51	35	43	37	37	50	38	40	66	54	43	36
Nd	23	33	30	36	20	18	15	23	14	20	54	36	29	19
Q	2.15	7.90	2.82	1.76	22.93	20.39	23.56	24.95	27.22	25.97	-	9.39	5.53	1.94
C	0.75	-	-	-	-	0.99	-	-	0.36	0.55	-	0.74	-	-
or	16.23	10.81	9.83	8.21	14.22	16.05	13.28	11.38	12.92	22.63	9.70	12.78	10.84	10.55
ab	31.68	35.31	24.99	39.78	34.45	35.20	30.57	33.02	28.94	28.67	38.01	32.01	24.57	28.25
an	25.88	22.92	31.04	22.89	18.12	18.84	20.60	19.44	20.31	13.17	26.10	24.89	29.30	30.29
di	-	4.88	6.93	7.38	0.44	-	0.36	0.34	-	-	5.70	-	6.30	4.06
hy	16.99	13.09	16.92	13.71	5.98	5.17	8.24	7.48	7.45	5.63	10.37	14.78	17.32	19.42
ol	-	-	-	-	-	-	-	-	-	-	2.84	-	-	-
mt	3.49	3.12	4.51	4.20	2.62	2.11	1.82	2.07	1.62	2.27	3.49	2.83	3.32	2.66
il	2.20	1.53	2.53	1.68	0.95	0.88	1.18	1.01	0.90	0.88	2.41	1.82	2.36	2.43
ap	0.63	0.44	0.44	0.40	0.28	0.37	0.40	0.30	0.28	0.23	1.38	0.77	0.47	0.40

Sets of analyses: GC 1 - GC 38, 9 even-grained diorites; GC 3 - GC 41, 7 acicular diorites; GC 15 - GC 92, 4 diorite xenoliths in granodiorite; GC 9 - GC 46, 6 granodiorites; GC 25 - GC 72, 4 dark diorite members of the inhomogeneous suite.

The inhomogeneous suite occurs as intrusive bodies each consisting of a wide variety of rock types which often have gradational contacts. Much of the suite comprises tonalite and a medium to light coloured quartz diorite, both of which enclose "xenolithic" material of darker diorite generally aligned with a sub-horizontal or gentle westward dip. The quartz diorite varies in texture from relatively even-grained to markedly acicular and frequently shows a continuous imperceptible gradation into tonalite. The tonalite, however, tends to concentrate towards the margins of the bodies. In addition to the main mass of the rock showing these variations in composition and texture, the "xenolithic" material also varies in appearance. Some of it, because of its angularity and proximity to even-grained diorite, is undoubtedly of even-grained diorite (see fig. 1d). The majority, however, is not even-grained diorite and ranges from distinct, through internally variable, areas with sharp boundaries to indistinct, shadowy patches with highly diffuse margins (fig. 1c and 1d) which finally become indistinguishable from the host rock. We consider, therefore, that all of these rock types, with the exception of the even-grained diorite xenoliths mentioned above, constitute a single petrogenetic group, the inhomogeneous suite.

Evidence of mobility between members of the inhomogeneous suite can be found along the foreshore on the northern side of Chouet where several exposures show dark diorite, quartz diorite and tonalite swirled together by turbid flow. Such evidence suggests to us that the various members of the inhomogeneous suite were, at least locally, above their respective solidus temperatures at the same time but that they did not completely intermix.

Relations between groups. The inhomogeneous suite is the youngest group of rocks. Its relationship to the granodiorite is clearly seen, for example, east of La Lochante where angular blocks of granodiorite are found completely enclosed within the inhomogeneous suite. Xenoliths within these blocks are cross cut (fig. 1b).

The relationships between the inhomogeneous suite and the diorite group may be seen at a number of localities. At low-water mark at Les Landelles partly detached, stoped-off blocks of even-grained diorite may be seen within the inhomogeneous suite but close to contacts with the main body of even-grained diorite (fig. 1d). On La Lochante, La Bennette and Les Landelles the even-grained diorite has been pervasively invaded by a tonalite which is part of the inhomogeneous suite. Contacts between the two rock types are usually markedly lobate and pipe-like bodies frequently occur. These pipes are similar in form to those described by Elwell et al. (1960) and consist of tonalite intruding upwards into even-grained diorite as cylindrical bodies up to a metre long and with diameters from 100 to 300 mm. Elwell et al. (1960) in discussion of the pipe-like bodies at Beaucette Battery, north-eastern Guernsey, have argued that they were produced during the remobilisation of a leucodiorite at the time of intrusion of an overlying meladiorite, which they infer to be later because of a supposed chilled margin against the leucodiorite. Bishop (1963), however, has warned that caution must be exercised in the interpretation of dark margins, particularly when associated with pipes. A remobilisation hypothesis is unnecessary in the case of the Chouet pipes since, despite the occasional presence of dark margins, there is no evidence to indicate

Table II (continued). Major element analyses (weight percent), selected trace element analyses (p.p.m.) and CIPW norms of rocks from Chouet, north-western Guernsey, Channel Islands.

	GC 7	GC 8	GC 11	GC 12	GC 20	GC 23	GC 24	GC 27	GC 28	GC 30	GC 31	GC 42	GC 43	GC 44	GC 45
SiO_2	61.25	64.09	65.92	67.64	59.94	66.21	60.33	58.84	58.19	61.36	60.44	59.51	56.45	56.48	58.08
TiO_2	0.62	0.55	0.46	0.45	0.74	0.55	0.75	0.95	0.91	0.63	0.62	0.84	0.96	1.07	1.01
Al_2O_3	19.93	18.41	17.68	16.75	20.04	17.11	19.31	18.71	18.84	19.58	19.94	19.30	19.27	19.29	18.63
Fe_2O_3	1.51	1.56	1.45	1.08	1.66	0.75	1.39	1.79	2.32	2.02	1.69	1.49	1.73	1.61	2.44
FeO	2.91	2.60	2.13	2.42	3.52	3.28	3.98	4.66	4.34	2.76	3.17	4.31	5.39	5.28	4.50
MnO	0.05	0.05	0.05	0.04	0.09	0.07	0.08	0.13	0.12	0.05	0.04	0.10	0.12	0.12	0.12
MgO	1.60	1.27	1.25	1.12	1.69	1.28	2.02	2.55	2.64	1.73	2.03	2.19	2.93	3.03	2.72
CaO	5.67	5.10	4.01	4.13	4.84	4.03	5.52	5.99	6.31	6.02	5.88	5.91	6.87	7.18	6.10
Na_2O	4.22	4.23	4.16	4.07	4.72	4.11	4.22	3.94	3.98	3.80	3.99	3.99	3.88	3.68	3.69
K_2O	2.01	1.95	2.72	2.17	2.50	2.44	2.12	2.13	1.91	1.81	1.98	2.06	1.99	1.80	2.28
P_2O_5	0.23	0.18	0.16	0.13	0.26	0.16	0.27	0.29	0.43	0.25	0.21	0.30	0.40	0.45	0.42
Sc	9	8	7	7	10	9	11	20	19	9	9	14	19	24	22
V	41	34	37	37	31	29	54	102	96	55	82	63	95	125	94
Cr	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.
Ni	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	3	n.f.	n.f.	n.f.	n.f.
Zn	32	35	35	22	47	31	51	60	66	33	29	51	62	56	54
Rb	54	48	80	55	73	65	62	65	60	48	69	59	61	54	79
Sr	544	518	584	506	599	461	554	561	553	496	635	586	545	520	552
Y	5	6	4	4	11	9	11	22	23	3	2	12	24	22	24
Zr	105	169	242	217	411	263	225	130	146	107	179	171	129	140	153
Ba	655	633	768	645	985	770	669	613	668	505	380	532	564	595	595
La	22	23	26	35	32	28	32	21	28	22	29	20	23	22	26
Ce	31	38	37	49	48	49	50	35	53	30	41	31	38	38	49
Nd	12	16	10	15	22	20	24	30	33	11	13	18	26	28	34
Q	13.69	18.49	20.39	24.21	8.94	20.73	11.30	9.49	9.45	16.45	13.04	10.84	5.52	6.84	9.77
C	1.06	0.50	0.99	0.51	1.40	0.75	0.69	-	-	1.03	1.04	0.48	-	-	0.02
or	11.86	11.50	16.05	12.80	14.77	14.41	12.52	12.59	11.28	10.67	11.68	12.18	11.77	10.64	13.48
ab	35.74	35.81	35.20	34.45	39.93	34.82	35.69	33.34	33.67	32.17	33.80	33.76	32.86	31.15	31.21
an	26.61	24.14	18.84	19.64	22.30	18.97	25.63	27.09	27.91	28.22	27.80	27.35	29.28	30.80	27.51
di	-	-	-	-	-	-	-	0.60	0.47	-	-	-	1.80	1.55	-
hy	7.13	5.83	5.17	5.67	8.24	7.82	10.09	11.81	11.12	6.75	8.52	10.94	13.52	13.61	11.58
ol	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
mt	2.19	2.27	2.11	1.57	2.41	1.08	2.02	2.59	3.36	2.93	2.45	2.16	2.51	2.34	3.54
il	1.18	1.05	0.88	0.86	1.41	1.05	1.43	1.81	1.74	1.20	1.18	1.60	1.82	2.03	1.93
ap	0.54	0.42	0.37	0.30	0.61	0.37	0.63	0.68	1.00	0.58	0.49	0.70	0.93	1.05	0.99

	GC 49	GC 50	GC 54	GC 57	GC 58	GC 59	GC 60	GC 61	GC 62	GC 63	GC 64	GC 65	GC 70	GC 71
SiO_2	57.83	58.71	57.96	58.49	56.96	56.66	56.71	58.78	57.97	56.62	58.90	58.36	59.92	57.29
TiO_2	0.88	0.82	1.03	0.93	1.05	1.11	0.81	1.00	0.96	1.02	0.81	0.74	0.69	0.95
Al_2O_3	20.06	19.85	18.49	19.58	19.64	19.02	20.03	18.30	19.92	19.54	19.95	20.77	20.29	19.78
Fe_2O_3	2.11	1.41	2.04	1.45	1.83	1.94	1.48	0.97	1.53	2.37	1.77	2.11	1.75	2.01
FeO	4.02	4.38	4.82	4.80	4.95	5.05	5.36	5.56	4.53	4.72	4.08	3.43	3.49	4.50
MnO	0.11	0.08	0.13	0.07	0.14	0.16	0.14	0.13	0.13	0.15	0.12	0.10	0.08	0.12
MgO	2.45	2.29	2.97	2.45	2.99	3.02	2.77	2.68	2.40	2.99	2.38	2.12	1.73	2.76
CaO	5.74	6.34	6.36	5.64	6.27	6.91	6.40	6.53	6.31	6.29	4.70	5.76	4.41	6.57
Na_2O	4.06	4.02	3.57	4.00	3.66	3.87	3.73	3.99	3.83	3.69	4.89	4.22	4.62	3.73
K_2O	2.36	1.77	2.22	2.23	2.04	1.71	2.08	1.61	2.01	2.13	2.10	2.12	2.78	1.90
P_2O_5	0.38	0.33	0.41	0.36	0.47	0.55	0.48	0.97	0.39	0.48	0.29	0.27	0.24	0.38
Sc	13	13	21	10	20	25	15	20	14	20	8	10	8	18
V	71	67	95	45	89	105	88	85	65	94	55	57	37	95
Cr	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.
Ni	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.
Zn	56	41	52	64	68	67	67	68	57	69	60	57	44	62
Rb	81	55	81	65	71	55	66	52	63	74	60	67	78	62
Sr	663	605	548	582	563	512	574	520	616	574	574	648	574	588
Y	11	10	24	11	23	29	20	32	13	28	11	6	11	13
Zr	140	147	139	443	175	51	60	206	274	184	334	315	387	148
Ba	447	391	629	890	674	484	707	425	535	598	549	572	910	571
La	28	25	24	24	24	27	23	30	20	24	23	21	14	23
Ce	47	41	45	37	54	57	39	56	36	47	41	35	22	37
Nd	22	19	32	22	33	47	28	42	20	39	22	14	12	20
Q	8.34	9.91	9.42	9.12	8.52	7.32	7.13	9.49	9.41	8.01	7.37	9.38	9.27	8.81
C	1.31	0.59	-	1.19	1.13	-	1.16	-	0.91	0.88	1.78	1.71	2.25	0.55
or	13.95	10.45	13.18	13.19	12.06	10.10	12.31	9.51	11.88	12.59	12.41	12.52	16.43	11.23
ab	34.34	34.01	30.20	33.86	30.97	32.77	31.58	33.80	32.40	31.22	41.40	35.68	39.08	31.55
an	25.96	29.29	27.86	25.62	28.04	29.46	28.59	27.26	28.75	28.07	21.42	26.82	20.29	30.11
di	-	-	0.83	-	-	0.99	-	1.87	-	-	-	-	-	-
hy	10.48	11.38	12.70	12.32	13.55	13.17	14.43	13.75	11.69	12.76	10.83	8.80	8.28	12.14
ol	-	-	-	-	-	-	-	-	-	-	-	-	-	-
mt	3.06	2.04	2.96	2.11	2.65	2.81	2.15	1.40	2.22	3.43	2.57	3.05	2.53	2.91
il	1.68	1.57	1.95	1.76	1.99	2.10	1.55	1.89	1.83	1.93	1.55	1.41	1.32	1.81
ap	0.88	0.77	0.96	0.84	1.10	1.28	1.12	1.03	0.91	1.12	0.68	0.63	0.56	0.89

GC 7 - GC 71, 29 quartz diorite and tonalite members of the inhomogeneous suite.

Table III. REE analyses of selected rocks from Chouet, north-western Guernsey, Channel Islands.

	GC 32	GC 34	GC 35	GC 36	GC 40	GC 10	GC 48	GC 45	GC 63	GC 8	GC 30	GC 31	GC 64	
SiO_2	53.81	50.57	54.71	57.72	51.73	67.54	54.58	58.08	56.62	64.09	61.36	60.44	58.90	
La	33.6	11.0	20.8	17.7	29.3	23.5	21.0	31.4	23.0	25.4	19.3	26.7	22.0	.315
Ce	66.0	18.9	36.1	37.4	53.7	35.2	50.0	56.5	59.0	41.6	26.5	38.2	44.0	.813
Pr	7.2	<2.3	5.0	4.3	6.6	4.7	6.5	7.0	7.6	4.0	<3.5	3.4	4.6	.116
Nd	29.8	12.3	22.7	28.4	38.1	17.5	28.2	41.8	37.3	14.4	11.0	11.1	19.2	.597
Sm	4.5	2.5	3.8	5.1	6.6	2.9	4.8	7.2	7.1	2.0	1.5	1.42	2.6	.192
Eu	1.32	1.03	1.35	1.45	2.5	1.07	1.42	2.2	1.85	1.20	0.85	0.83	1.38	.0722
Tb	0.53	0.32	0.44	0.62	0.74	0.30	0.63	0.80	0.90	0.204	0.14	0.094	0.296	.047
Dy	3.8	2.6	3.4	4.2	4.9	2.6	4.5	5.3	6.1	1.9	0.98	1.0	2.2	.325
Ho	0.61	0.36	0.53	0.65	0.85	0.29	0.68	0.68	0.93	0.25	0.15	0.10	0.35	.0718
Yb	3.6	1.5	2.0	2.8	3.2	1.4	3.15	3.0	4.1	1.38	0.56	0.51	2.1	.208
Lu	0.61	0.19	0.32	0.43	0.48	0.20	0.51	0.45	0.64	0.24	0.08	0.89	0.363	.0323
Ce/Yb	4.7	3.2	4.6	3.4	4.3	6.5	4.1	4.8	3.7	7.7	8.0	19.2	5.4	-
Eu*	-	10.5	15.3	-	26.8	11.3	-	28.9	29.8	7.8	5.7	4.8	10.4	-
Eu/Eu*	-	1.36	1.22	-	1.29	1.31	-	1.06	0.86	2.14	2.09	2.42	1.84	-

Even-grained diorite (GC 32, 34, 35, 36); Acicular diorite (GC 40); Granodiorite (GC 10); Inhomogeneous suite, dark diorite (GC 48), quartz diorite (GC 45, 63), tonalite (GC 8, 30, 31, 64). Ratios calculated using chrondrite values from Sun & Hanson (1976), given in the right-hand column. Analyst: G.R. Gilmore that the diorite group post-dates the inhomogeneous suite. However, the ductile behaviour of the even-grained diorite leads us to conclude that at least parts of it must have been at or near its solidus temperature at the time of pipe formation.

The relationship between the granodiorite group and the diorite group is less obvious than the other relationships because the two groups are rarely ~~seen~~ in contact. Sheets and small irregular boss-like bodies of granodiorite appear to have been emplaced into the even-grained diorite in the Mont Cuet quarry and in several of the disused quarries around Chouet. Similar bodies occur on Roche du Pezeril (fig. 1a) and immediately east of this locality where the granodiorite may be seen to vein even-grained diorite. Thus we conclude that the granodiorite group post-dates the diorite group but pre-dates the inhomogeneous suite. In some ways this is an inconvenient solution since it presents the problem of how the diorite group could have been locally close to its solidus at the time of emplacement of the inhomogeneous suite while the granodiorite was included in the inhomogeneous suite as angular blocks. Nevertheless, it is the solution supported by the field evidence.

Petrography

The diorite group. The even-grained diorite normally has sufficient quartz in the mode (fig. 2) to qualify as quartz diorite (Streckeisen, 1976). It contains euhedral to subhedral plagioclase which shows discontinuous normal zoning from bytownite or calcic labradorite to calcic or middle oligoclase. In contrast, the acicular diorite contains plagioclase which is strongly sericitised and is zoned from middle andesine to sodic oligoclase. Hornblende in the even-grained diorite occurs as equant, subhedral, brownish-green crystals whereas in the acicular diorite a mixture of equant and acicular prismatic amphibole crystals is present. The acicular crystals often contain ragged flakes of biotite and generally have lobate margins with plagioclase, especially where biotite is rare. Brown biotite is variable in the modes of the diorites (fig. 2) but when present as large plates it poikilitically encloses small, rounded, strongly zoned plagioclase laths. Prehnite wedges are developed along the biotite cleavages, particularly in the acicular diorite. Magnetite and euhedral apatite are ubiquitous accessory minerals. Sphene occurs sporadically in the even-grained diorite but is common in the acicular diorite where it occurs interstitially. Large subhedral zircons are present in the acicular diorite.

The overall texture of the even-grained diorite is of igneous origin. This is indicated by the plagioclase zoning (e.g. Sibley et al., 1976) and the poikilitic nature of the hornblende and biotite crystals. There is no evidence that the hornblende formed by replacement of primary igneous pyroxene as has been demonstrated for certain diorites elsewhere (e.g. Wells and Bishop, 1955; Gulson, 1972). The texture of the acicular diorite is also one predominantly produced by igneous processes, the greater development of prehnite, the acicular prismatic habit of the amphibole and sericitisation of the plagioclase all suggest a higher activity of volatiles than in the even-grained diorite.

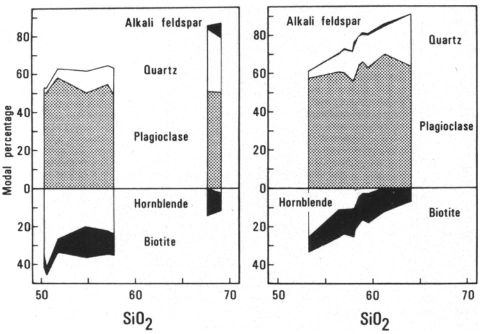

Fig. 2. Modal percentage of the main minerals vs, SiO_2 content in Chouet rocks. Left, five members of the diorite group and two members of the granodiorite group. Right, nine members of the inhomogeneous suite ranging from dark diorite through quartz diorite to tonalite.

The granodiorite group contains rocks which straddle the boundary between granodiorite and tronhjemite (Streckeisen, 1976). They are medium- to coarse-grained, plagioclase, quartz, biotite rocks in which the quartz forms polycrystalline aggregates. Minor amounts of K-feldspar occur interstitially with the quartz. The euhedral to subhedral plagioclase crystals exhibit discontinuous normal and oscillatory zoning both within the andesine-oligoclase range and, more rarely, patchy zoning. Minor anhedral, green hornblende is found in addition to accessory apatite and magnetite. Sphene and zircon are sometimes present.

The inhomogeneous suite. The wide variation in composition of this suite from meladiorite to leucotonalite results in rocks with variable proportions of plagioclase, quartz, biotite, hornblende, magnetite and occasional perthitic alkali feldspar (fig. 2). Normal and oscillatory zoned plagioclase ranges in composition from middle andesine to sodic oligoclase. Patchy zoning is also present, more commonly in the tonalite. Brown biotite poikilitically encloses small plagioclase laths and is found interstitially around larger plagioclases. Green hornblende is present throughout most of the suite and occurs as both equant and acicular crystals in many of the quartz diorites. The acicular crystals may have lobate margins and often contain and replace biotite. Accessory minerals include euhedral apatite, zircon and interstitial sphene and prehnite occurs along biotite cleavages.

Geochemistry

Rock specimens for analysis were chosen to provide a representative sample of each rock group. Any system of sampling in such a complex area must introduce some bias but the approach adopted is considered preferable to attempting any kind of systematic grid or traverse sampling. Fifty nine specimens covering the range of rock types were analysed using X-ray fluorescence spectrometry on pressed powder discs following the method of Brown et al. (1972). Major element values are expressed on a water-free basis recalculated to 100%. The analyses are presented in Table II. The REE were determined by Dr. G.R. Gilmore at the Universities Research Reactor, Risley, U.K. by a neutron activation method and are given in Table III.

The analyses have been plotted on Harker-type diagrams (figs. 3,4 and 5), chondrite normalised REE plots (fig. 6) and an AFM diagram (fig. 7).

The diorite group. The even-grained diorite specimens are shown on the geochemical plots as solid squares. With increasing SiO_2 these specimens show decreasing Al_2O_3, MgO, CaO, Sc, V, Cr and Ni and increasing Na_2O, La, Nd and Y whilst P_2O_5, MnO, Sr, Zn and Ce show little systematic change. Some of the elements, FeO + Fe_2O_3, TiO_2, Rb, Ba and Zr, increase up to about 55% SiO_2 and then decrease. Despite a strong correlation of K with Rb, K/Rb shows no consistent variation with increasing SiO_2. The total REE contents of four specimens of even-grained diorite (Table III and fig. 6) show a general increase with increasing SiO_2. However, no relative enrichment in LREE with increasing SiO_2 is apparent, contrary to that which has been recorded in some other sequences ascribed to fractionation (note normalised Ce/Yb in Table III).

The acicular diorite, plotted as open squares, spans a similar range of SiO_2 content to the even-grained diorite although it generally has higher TiO_2, P_2O_5, Sr, La, Ce, Nd and Y and, for the one specimen analysed, total REE content. In marked contrast to the even-grained diorite, nearly all specimens of acicular diorite are below the theoretical detection limit for the elements Cr and Ni (7ppm and 2ppm, respectively).

The granodiorite group. All specimens analysed from the granodiorite group have a higher SiO_2 content than any of the other rock types with a single exception. These specimens, which are plotted as five-pointed stars, are very similar in geochemistry. A significant feature of their geochemistry is the presence of Cr and Ni in detectable amounts. The specimen of granodiorite analysed for REE shows a lower total REE content than most of the specimens of even-grained diorite, accompanied by a relative depletion in HREE (normalised Ce/Yb = 6.46). Judging by the high La/Y ratios of the other specimens of granodiorite this relative depletion in HREE is likely to be present throughout the granodiorite group.

Four xenoliths from the granodiorite were analysed and are plotted as eight-pointed stars. Their chemistry is very similar to that of the even-grained diorite, Cr and Ni are present in the xenoliths in levels comparable to those in the even-grained diorite. In contrast to the granodiorite, the xenoliths have very low La/Y ratios and they may be relatively enriched in HREE, perhaps as a result of slight reaction between granodioritic magma and diorite.

The inhomogeneous suite. The quartz diorites and tonalites of the inhomogeneous suite are plotted as filled circles and the dark diorites as diamonds in the variation diagrams. There are a number of features of these diagrams which cannot be explained in terms of a simple fractionation model relating the inhomogeneous suite to the even-grained diorite. These two groups show different trends on the plot of Al_2O_3 against SiO_2 (fig. 3) and their P_2O_5 contents are generally quite different. Furthermore, the trend of variation of P_2O_5 against SiO_2 for the inhomogeneous suite (moderate negative slope) is not continuous with that for the even-grained diorite (shallow positive slope) but cuts across it (fig. 3). Finally, all members of the inhomogeneous suite, even the most SiO_2 poor, contain no detectable Cr and Ni in contrast with the moderate amounts in the even-grained diorites.

Geochemical variation within the inhomogeneous suite is extensive, particularly in the tonalitic members. The remarkably wide ranges in Zr, Ba and to a lesser extent Sr are especially noteworthy. These variations which occur in the very small SiO_2 range covered by the tonalites apparently may not be restricted to Chouet tonalites (see, for example, Busrewil et al., 1975) but might be a general feature of rocks of this complex type.

The REE analyses for the inhomogeneous suite fall into two sets (fig. 6), one containing four analyses of tonalites, the other two quartz diorites and one darker diorite. The REE patterns of this latter set are similar to those for the even-grained diorites which, however, have slightly lower total REE contents. All members of the tonalite set have lower total REE contents than the other analyses of the inhomogeneous suite. They show pronounced positive Eu anomalies (Eu/Eu* = 1.84 to 2.42) and relative HREE depletion (normalised Ce/Yb = 5.4 to 19.2). The high values of La/Y for the tonalites compared with the other members of the inhomogeneous suite are consistent with HREE depletion. These features of the REE distributions of the inhomogeneous suite are very similar to those presented by Arth et al. (1978) for certain diorites and tonalites from Finland.

Petrogenesis

The diorites and associated rocks of the Chouet area plot in the AFM diagram on a well defined calc-alkaline trend showing no middle stage iron enrichment (fig. 7). The high values of Al_2O_3, high FeO/MgO, and low abundances of Cr and Ni are also characteristic of calc-alkaline rocks. These general features frequently have been interpreted as indicating a suite of rocks related by crystal fractionation, although in many cases they could equally be produced by progressive fractional melting of a hydrous basic or ultrabasic source. For either of these alternatives it seems likely that an amphibole is involved either as a fractionally crystallising phase (e.g. Cawthorn and O'Hara, 1976) or as a residual phase to fractional melting (e.g. Barker and Arth, 1976).

In the present case, however, a single fractional crystallisation, or a single progressive fractional melting model does not explain adequately the various differences and discontinuities between the three main rock groups in the Chouet area. For example, the inhomogeneous suite, which, in general, covers the middle range of compositional variation of the series as a whole, clearly post-dates both the diorite and the granodiorite groups. In any case, it is difficult to envisage how a single fractionation model might produce such gross inhomogeneity only in its middle stages. As far as the SiO_2 content is concerned, an area of overlap occurs between the inhomogeneous suite and the even-grained diorite in the range 53-59%. The geochemical characteristics of the two groups differ in this area for a number of elements, e.g. P_2O_5, Sc, V, Ce, Nd and Y. This contrast takes the form of an intersection or of a change in slope of the

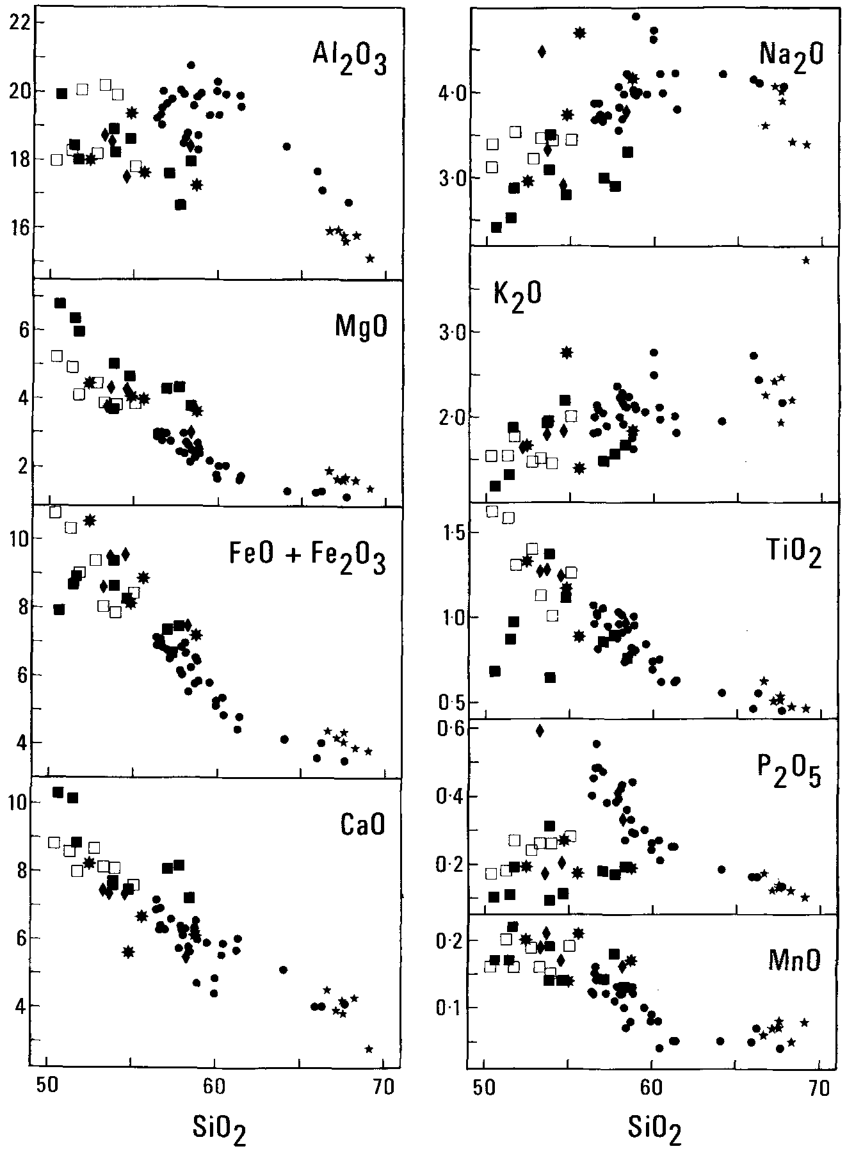

Fig. 3. Plots of oxide vs. SiO_2 for Chouet rocks. In this and subsequent figures: filled squares - even-grained diorite; open squares - acicular diorite; 5-pointed stars - granodiorite; 8-pointed stars - diorite xenoliths in granodiorite; diamonds - dark diorite members of the inhomogeneous suite; filled circles - quartz diorite and tonalite members of the inhomogeneous suite.

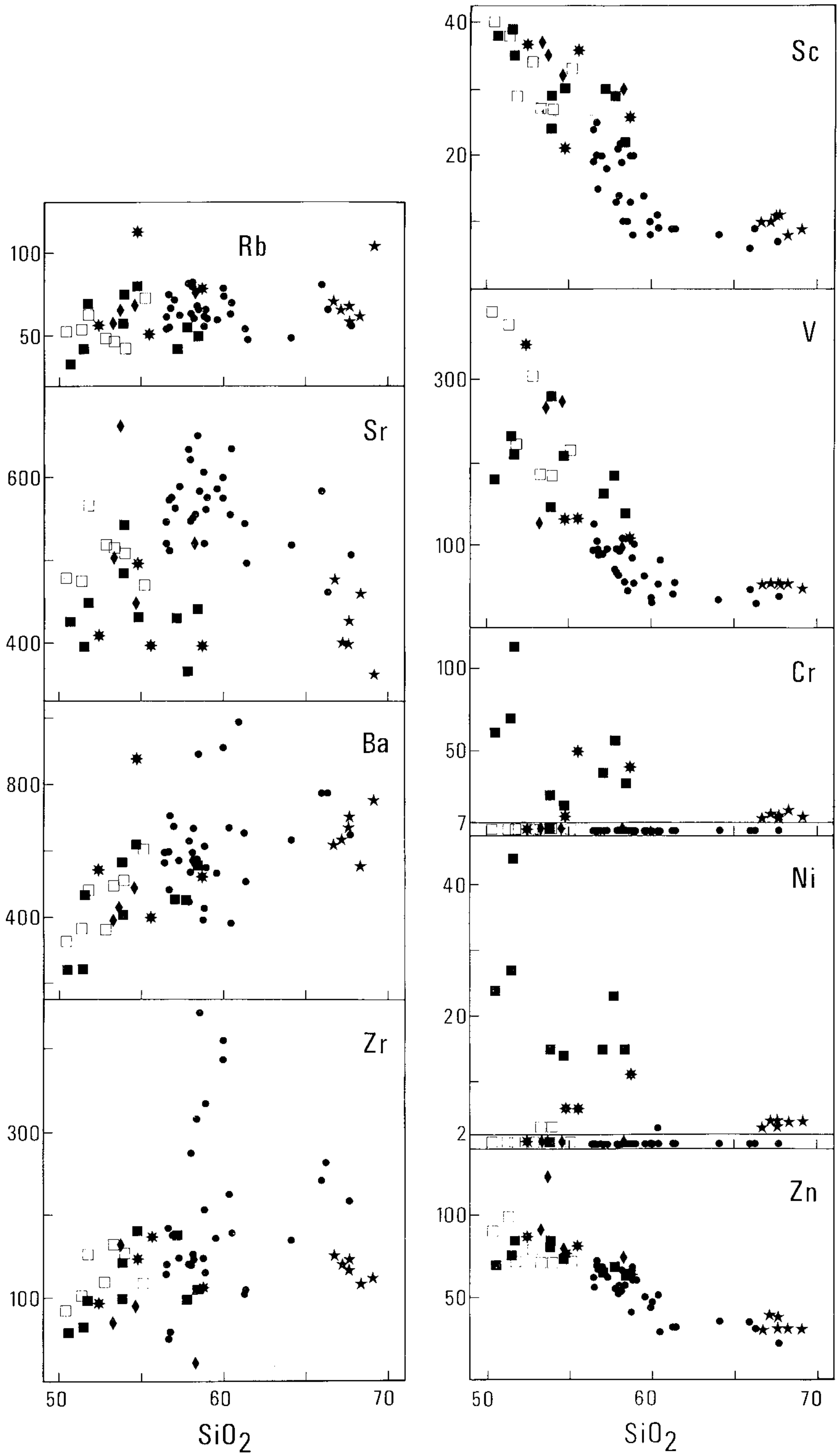

Fig. 4. Plots of selected trace elements vs. SiO_2 for Chouet rocks. Symbols as in fig. 3.

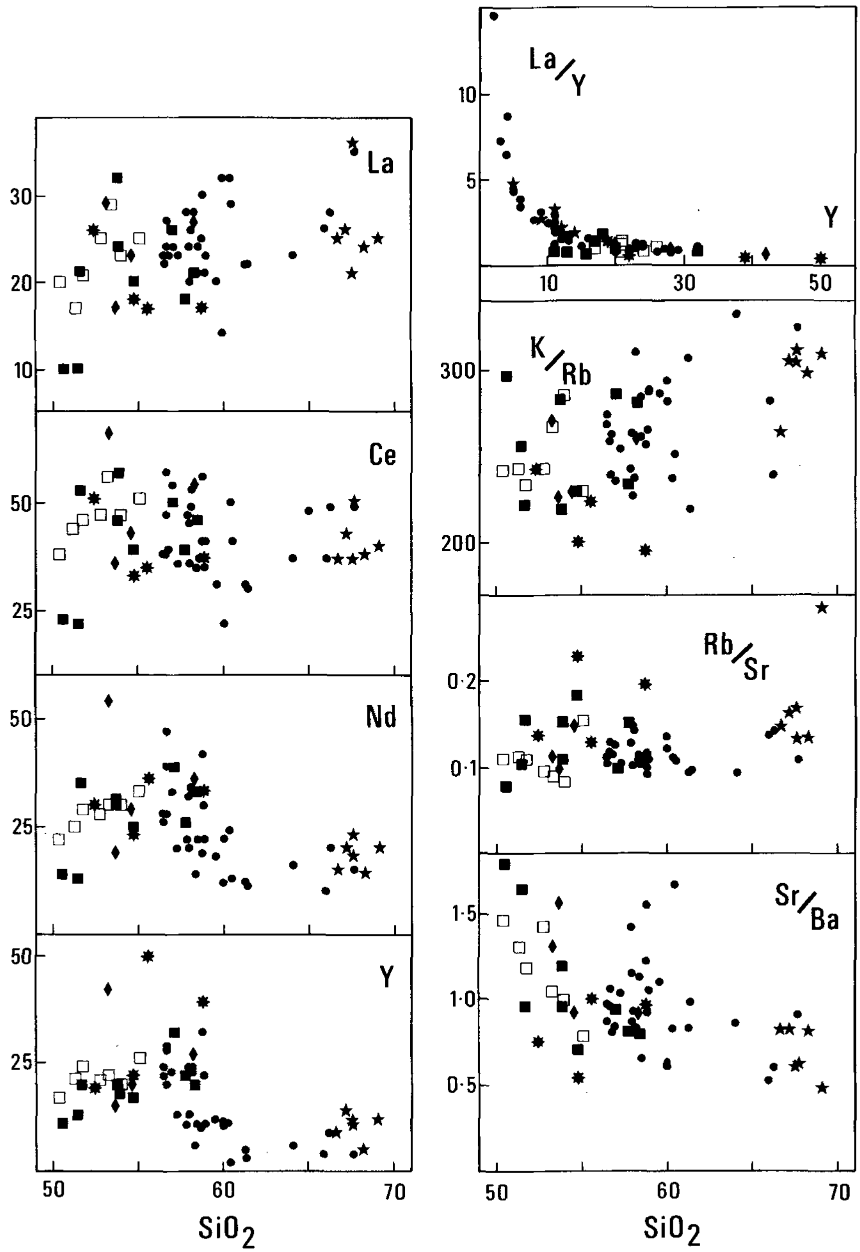

Fig. 5. Plots of selected rare earth elements, Y, K/Rb, Rb/Sr and Sr/Ba vs. SiO_2 and of La/Y vs. Y for Chouet rocks. Symbols as in fig. 3.

trends of the groups (figs. 3, 4 and 5). Also, in the range 53-59% SiO_2 the Al_2O_3, Sr, Cr and Ni abundances of the two groups are rather different. The Cr and Ni contents throughout the inhomogeneous suite are characteristically very low even in the most SiO_2 poor parts, whereas the even-grained diorite shows a more normal Cr and Ni variation.

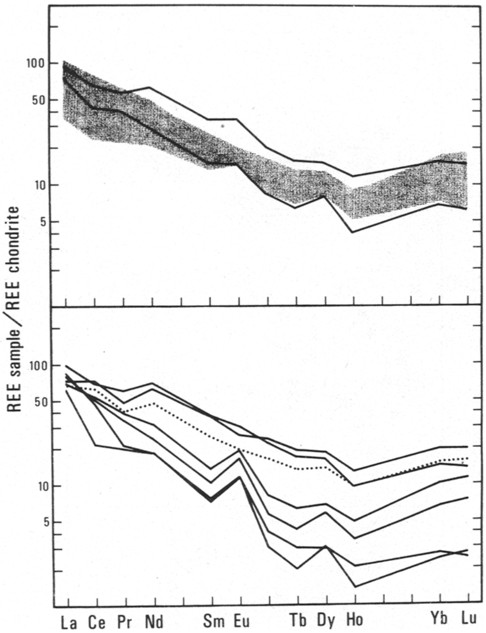

Fig. 6. Chondrite normalised REE plots of thirteen of the Chouet rocks. Upper diagram: one granodiorite (lower curve); five diorite group comprising four even-grained diorites (shaded area) and one acicular diorite (upper curve). Lower diagram: seven inhomogeneous suite comprising one dark diorite (dotted curve), two quartz diorites (upper curves) and four tonalites (lower curves).

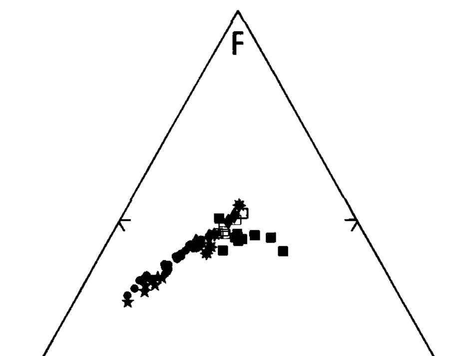

Fig. 7. AFM plot for Chouet rocks. Symbols as in fig. 3.

The diorite group. Despite the arguments against a single fractional crystallisation or melting model for the derivation of all three main rock groups, the field relations, petrography and geochemistry of the even-grained diorite specimens alone are consistent with a related origin by fractional crystallisation. Petrographic study of the textures of these diorites has shown that hornblende + plagioclase are likely liquidus phases (see petrography section) and the variation seen within this rock type up to 55% SiO_2 content may be attributed to hornblende + plagioclase fractionation. Such an interpretation is consistent with the geochemical variation and, in particular, with the observation that no middle stage iron enrichment occurs.

Arth et al. (1978) quote the REE partition coefficients for amphibole/groundmass in basalts and andesites as being less than one. Amphibole fractionation would thus have the effect of increasing the total REE content with increasing SiO_2, as is observed in the Chouet even-grained diorites. The lack of a Eu anomaly might be accounted for by the balanced fractionation of amphibole and plagioclase.

A change in the slopes of FeO + Fe_2O_3, Rb, Zr and Ba against SiO_2 occurs at about 55% SiO_2 and this is taken to indicate the entry into the fractionation scheme of a third phase which preferentially incorporates these elements; both the petrography and the geochemistry are consistent with this phase being biotite. Thus we interpret the later part of the fractionation trend of the even-grained diorite as being produced by amphibole + plagioclase + biotite fractionating out with biotite entering as an important liquidus phase at about 55% SiO_2.

The abundances and variation in the immobile elements Cr and Ni for the even-grained diorite might suggest that some even earlier fractionation than that represented by the rocks of the Chouet area, probably of olivine ± pyroxene ± amphibole, has occurred. In this respect the proximity of St. Peter Port Gabbro (see fig.2 of synopsis) is of interest. This intrusion, which predates the Bordeaux Diorite (Drysdall, 1957; Roach, 1966), is a layered olivine gabbro and hornblende gabbro-bojite complex in which fractionation, precisely of these phases, has been demonstrated to occur (Roach, 1971). We do not dismiss the possibility that the even-grained diorite of Chouet is the product of a liquid derived by fractionation of the St. Peter Port Gabbro magma.

Two possible models might be envisaged for the origin of the acicular diorite, a model based on metasomatism of the even-grained diorite or one based on delayed magmatic crystallisation of parts of the diorite group liquid. Using a metasomatic model, it is difficult to explain the complete removal of Cr and Ni from the even-grained diorite as these elements tend to be partitioned into the solid phases and normally are considered to be immobile during metasomatism. The preferred model, therefore, is that the acicular diorite represents local fractions of the diorite group liquid whose crystallisation was delayed compared with that of the even-grained portions because of higher volatile content. Such a mechanism is consistent with the generally higher P_2O_5, Sr and REE contents of the acicular diorite and with its more marked sericitisation and prehnite development. It gains support from the observations of Piwinskii (1967) that acicular crystals form under quench conditions in H_2O-rich liquids. Under such conditions the very low abundances of Cr and Ni in the later crystallising portions are to be expected. The small pods and veins of appinite which occur within the acicular diorite might either represent even more volatile rich patches, or some or all of them may have been produced by local remobilisation and recrystallisation of the acicular diorite in response to the emplacement of the inhomogeneous suite (c.f. Key, 1977). In either case it seems likely that the appinite crystallised under quench conditions, probably initiated by the sudden loss of valatiles. Cored amphiboles are typically developed in the Chouet appinites and have been produced experimentally by quenching of dioritic compositions (Condliffe, 1973).

The granodiorite group. Since there are no rocks of suitable composition to provide a direct link by liquid descent between the even-grained diorite and the granodiorite, we conclude that the diorite group and the granodiorite group are genetically unrelated. The two most likely origins for the granodiorite group are either as a direct melt from a lower crustal source or as the end product of fractionation of a melt not represented by any other rocks at the present erosion level. We have no evidence to enable us to distinguish between these possibilities.

The inhomogeneous suite. For the reasons previously stated, the field relations and the geochemical variation of the inhomogeneous suite demonstrate that it cannot be derived from the diorite group magma by simple crystal fractionation. Similar inhomogeneous rocks often are ascribed to an assimilitive origin (e.g. Read and Haq, 1965) or, more rarely, to an origin by hybridisation (e.g. Wiebe, 1970). In the case of the inhomogeneous suite of Chouet, however, examination of the plots of Al_2O_3, P_2O_5, Zr, Cr, Ni, Ce, Nd and Y against SiO_2 demonstrates rather clearly that the variation within the inhomogeneous suite cannot be produced by mixing between any presently exposed members of the diorite group and either the granodiorite group of any member of the inhomogeneous suite itself, since the linear trends predicted by such a model (e.g. Gunn and Watkins, 1969) are absent. In this respect it should be noted that the darker dioritic portions of the inhomogeneous suite are not partially assimilated xenoliths of the even-grained diorite from which they may be distinguished both by their different appearance in the field and by their different trace element contents.

The general range and linear variation for most of the major elements and many of the trace elements within the inhomogeneous suite, however, indicate that the members of the suite share a related origin by fractionation. It is envisaged that the darker dioritic material represents the early-formed solid or semi-solid crystalline mush, intruded, broken up and partially redigested by the later fractionated liquid of quartz diorite and eventually tonalite composition. The inhomogeneous suite of the Kennethmont Complex may have been formed by a similar mechanism (Busrewil et al., 1976).

Petrographic evidence demonstrates that zoned plagioclase feldspar was always an early crystallising phase in the inhomogeneous suite, variably accompanied by hornblende, biotite, apatite and magnetite. A clear and complete demonstration of the extent of fractionation of all these phases is impossible. Despite the uncertainty of the extent of apatite fractionation some indication of the role played by hornblende and plagioclase may be gained by a study of the REE plots already described (see geochemistry). The increase in total REE content from the darker dioritic material to the quartz diorites requires that a phase with a partition coefficient of less than one has fractionated out and hornblende seems the most likely phase. The absence of a Eu anomaly of any kind in these early members indicates that although plagioclase was fractionated out its effect was counteracted by hornblende. The lower total REE content of the tonalites might also be explained by hornblende fractionation since Arth et al.(1978) report that partition coefficients for hornblende in dacite are greater than one for LREE and as high as six for HREE. In this way the relative HREE depletion might also be explained. The presence of the marked Eu anomalies in the tonalites is very probably accounted for by the high modal plagioclase.

The explanation of the striking and unusual variations of certain trace element contents, notably Sr, Ba and Zr, is not clearly understood. More information on the behaviour of these elements in dioritic and tonalitic rocks is desirable.

Conclusions

1. In the Chouet area three distinct rock groups have been established: a diorite group comprising even-grained diorite and acicular diorite; a granodiorite; and an inhomogeneous suite of rocks comprising dark diorite, quartz diorite and tonalite. Each rock group has its own distinctive chemistry and contrasting trends of geochemical variation and they cannot easily be related to each other by simple differentiation.

2. The variation within the even-grained diorite is wholly consistent with a model involving the fractionation of hornblende + plagioclase up to 55% SiO_2 and hornblende + plagioclase + biotite at higher SiO_2 contents. The acicular diorite was derived from the diorite group magma by delayed crystallisation of volatile-enriched portions.

3. The granodiorite group liquid may represent the fractionated derivative of some other magma, but if this is the case the "parent" is *not* represented by rocks exposed around Chouet. Alternatively, the granodiorite may represent a direct crustal melt.

4. The inhomogeneous suite crystallised from a different liquid to the other rock groups and the dark diorite, quartz diorite and tonalite members of the suite are related to each other by fractionation of this liquid. The inhomogeneity of the suite is a result of later differentiated liquids being intruded into and partly digesting the earlier-formed semi-solid material.

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